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Cochlear nerve spontaneous activity supports the detection of low level acoustic signals

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In this study simulated noisy spiking patterns of the cochlear nerve were classified by artificial neural nets in order to determine the threshold of hearing for pure tones.
The spontaneous spiking activity in the highly sensitive primary auditory afferents is assumed to be caused primarily by inner hair cell (IHC) receptor potentials which arise due to stochastic opening of transduction channels in the stereocilia, initiated by both stereociliary Brownian motion and the stochastic component of the gating mechanism. Very weak tones close to hearing threshold do not cause a significant change in the total spiking rate, but a rearrangement of the spikes: with increasing signal to noise ratio, the spikes become more and more phase-locked to the weak sinusoid. Without the contribution of the voltage fluctuations due to Brownian motion the voltages caused by the weak signal would be subthreshold and not evoke spikes at all.
Simulated Brownian motion of IHC stereocilia with rms amplitudes of 2-3nm together with low level acoustic inputs were used as input for an electric network model to calculate the receptor potential. Distribution of receptor potential peaks to activate different release zones close to the bottom of the hair cell and adjusted exponential recovery behavior generated about 100 spikes/s in a primary auditory fiber with high spontaneous activity. Artificial neural nets that are trained in order to detect regularities in the interspike times can classify the neurograms with a performance comparable to that of the brain: A single fiber needs about 2 seconds to sample enough information to decipher a 500 Hz tone with a signal to noise ratio of 1/10. This result is equivalent to 20 ms signal presentation time, if one considers 100 highly sensitive fibers connecting to adjacent IHC from the same tonotopic region, i.e. these 100 fibers originate from the region where the basilar membrane vibrates sufficiently.
This modeling study indicates that the threshold of hearing is reached when the amplitude of the stereociliary movement due to weak auditory signal is at least one order of magnitude below that caused by Brownian motion.